Biological Control **22,** 139–148 (2001)
doi:10.1006/bcon.2001.0968, available online at http://www.idealibrary.com on IDEAL®

The Brazilian Peppertree Drupe Feeder *Megastigmus transvaalensis* (Hymenoptera: Torymidae): Florida Distribution and Impact

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Received September 15, 2000; accepted May 25, 2001; published online August 13, 2001

An introduced torymid wasp, *Megastigmus transvaalensis*, originally reared from *Rhus* spp. in South Africa, was recovered from drupes of the terrestrial weed *Schinus terebinthifolius* in Florida. Collections of *S. terebinthifolius* drupes in Florida during a 2-year period indicated that *M. transvaalensis* was present at all 18 sites surveyed and this was the only insect that emerged from these drupes. Dissections of drupes collected during the winter fruiting period indicated that wasps damaged 23.5 ± 2.8% of the drupes during 1997–1998 and 38.5 ± 4.2% of the drupes during 1998–1999. During the spring fruit production period, 76.3 ± 3.6% of the drupes were damaged by the wasp in 1998 and 74.8 ± 3.4% during the same period of 1999. Germination tests of wasp-damaged drupes indicated that none of the infested seeds were viable. Purportedly diapausing wasps emerged more rapidly from rearing conditions that included a 12-h compared to a 14-h photoperiod. Utilization of alternate hosts was not detected despite attempts to rear the wasp from drupes of the native species within and outside the Anacardiaceae family found in the Florida range of *S. terebinthifolius.*

***Key Words:* Anacardiaceae; diapause; impact of biological control; nontarget effects; reproductive potential; *Schinus terebinthifolius;* weed biological control.**

INTRODUCTION

The Brazilian peppertree, *Schinus terebinthifolius* Raddi (Anacardiaceae), is a native of Brazil, Paraguay, and Argentina (Ewel *et al.*, 1982) and was introduced into Florida as an ornamental shrub during the latter half of the nineteenth century (Bennett and Habeck, 1991). Brazilian peppertree is ranked among the most important threats to biodiversity in the south Florida ecosystem (Ewel, 1986), it occupies more area in the state than any other invasive weed species (Schmitz, 1994), and is estimated to cover more than 4000 km^2 of Florida public land (Ferriter, A., SFWMD, West Palm Beach, FL, personal communication). The species is well known for its copious production of monocarpic, bright red fruits during the winter that may remain on the trees for many months. A well-known invader of disturbed sites, this species also colonizes undisturbed native plant communities including pinelands, hammocks, and mangrove coastal areas of Florida (Ewel *et al.*, 1982; Mytinger and Williamson, 1987; Johnson, 1994). The plant may grow to 10 m in height, forming dense monospecific thickets. Not only is the shrub a threat to biodiversity but volatiles produced by the flowers can be detrimental to humans as they can cause sinus and nasal congestion, headaches, sneezing, eye irritation, and labored breathing (Morton, 1978). Additionally, ingestion of the drupes by birds may cause intoxication (Campello and Marsaioli, 1974) and the sap from wood causes severe rash and intense discomfort in susceptible humans (Morton, 1978). The plant is found in central and southern Florida, southern Arizona, southern California, Hawaii, Puerto Rico, and St. John, Virgin Islands (Little *et al.*, 1974). Its distribution in Florida extends from the Florida Keys north to Cedar Key on the west coast and to St. Johns County on the east coast (Wunderlin, 1998).

Biological control of this species was initiated in Hawaii in the 1950s and resulted in the release of a defoliating caterpillar, *Episimus utilis* Zimmerman (Lepidoptera: Tortricidae), a gall-forming caterpillar, *Crasimorpha infuscata* Hodges (Lepidoptera: Gelechiidae), and a seed-feeding beetle, *Lithraeus atronotatus* (Pic) (Coleoptera: Bruchidae) (Julien and Griffiths, 1998). Only *E. utilis* and *B. atronotatus* have established in Hawaii but apparently they have had little impact on the target weed populations (Yoshioka and Markin, 1991). Similar biological control efforts have been ongoing in Florida for over 10 years, and just recently a petition has been made for field release of a

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sawfly, *Heteroperreyia hubrichi* Malaise (Hymenoptera: Pergidae) (Medal *et al.*, 1999).

Surveys of the insect fauna associated with Brazilian peppertree in Florida have recovered 115 species, 40% of which were herbivorous (Cassani, 1986; Cassani *et al.*, 1989). None of the species is considered a promising agent for the reduction of Brazilian peppertree populations as none causes significant damage to the plant, most are generalist feeders, and a few are potential agricultural pests. However, a recent arrival to Florida feeds on the drupes of Brazilian pepper tree. This species, *Megastigmus transvaalensis* (Hussey) (Hymenoptera: Torymidae), was probably introduced accidentally from Réunion or Mauritius via France in Brazilian peppertree fruits sold as pink peppercorns in exotic food stores (Habeck *et al.*, 1989). In Réunion, drupes harvested in 1979 from invasive populations of *S. terebinthifolius* produced 60 tons that were exported to Europe and the United States (E. E. Grissell, USDA/ARS, Washington, DC, personal communication). This wasp species was also reported from Hawaii (Beardsley, 1971) where it was suspected of displacing the biological control agent *L. atronotatus* (Yoshioka and Markin, 1991). Additionally, the wasp has been collected from the Canary Islands (Grissell, 1979), Argentina (G. S. Wheeler and H. A. Cordo, unpublished data), Brazil (Grissell and Hobbs, 2000), and California (Harper and Lockwood, 1961). The host range of this species includes at least three South African *Rhus* species, including *Rhus laevigata* L. and *R. angustifolia* L. (Grissell and Hobbs, 2000), and the South American *Schinus molle* L. (Hussey, 1956; Grissell, 1979; Yoshioka and Markin, 1991). In Florida, this species has been reported only from *S. terebinthifolius* fruits (Habeck *et al.*, 1989); however, considering its purported South African *Rhus* origin (Grissell and Hobbs, 2000), it may constitute a threat to Florida's native members of the Anacardiaceae.

The goals of this study were to (1) describe the Florida distribution of *M. transvaalensis* and the dynamics of wasp emergence, (2) determine the impact of the wasp on the reproductive output and seed viability, (3) determine the importance of photoperiod as a factor influencing emergence from diapause, and (4) examine the host range of this wasp from native Florida members of the Anacardiaceae.

METHODS AND MATERIALS

Sample collection, wasp emergence, and damage. Collection sites were established throughout the range of Brazilian peppertree in Florida. A total of 18 sites were sampled during a 2-year period (1997–1999). Sites were located from the Everglades National Park in the south to Tampa Bay on the west coast, Daytona Beach on the east coast, and Orlando in the center of the state (Fig. 1). Samples consisted of three to four collections of 100–500 drupes each during the fruit-production season. Drupes that were freshly produced, mature, and bright red in color were collected. Previous observations indicated that wasps would not emerge unless the drupes were mature and orange or red at the time of collection. Collections for the 1997–1998 season were made during the fall (9 Oct.–5 Dec.), winter (4 Feb.–2 Mar.), and early summer (25 Jun.–12 Jul.). This early summer fruiting was unexpected as this species is well known to produce fruit synchronously primarily during the fall/winter. However, about 10% of the female *S. terebinthifolius* trees of south Florida produce fruit during this period (Ewel, 1986). All sites were visited during this period and, when present, drupes were collected. To determine the diversity of drupe-feeding insects, all drupes collected during the winter and fall were reared in a screenhouse under ambient conditions either in screened glass jars (3.8 liter) or petri dishes (9×1.5 cm) and observed one to three times per week for insect emergence. After a 2-week period during which no wasps emerged, the drupes were moved to environmental chambers to determine the effect of photoperiod on breaking diapause (see Breaking diapause below). Wasp emergence dates were recorded only for fall and winter collections.

During year 2 (1998–1999) drupes were collected only once during the fall/winter (5 Dec.–13 Jan.) at each site as no difference was found in the damage levels in these two seasons during year 1 (see Results). Additionally, samples were collected during spring (9 Jun.–24 Jun.) where fruit were available. Although some of these drupes may have been collected in early summer, this will be described throughout as the spring collection. The drupes collected during year 2 were incubated in an environmental chamber at 28°C; 12:12 h light:dark photoperiod. Wasp emergence dates were recorded for both winter and spring collections.

To test the hypothesis that the wasp *M. transvaalensis* was introduced to Florida in *S. terebinthifolius* drupes sold as pink peppercorns (Habeck *et al.*, 1989), the presence of wasps or wasp damage was determined from three commercially available pink peppercorns purchased from local (Ft. Lauderdale, FL) spice shops. The drupes of these commercial sources were all *S. terebinthifolius* from Morton & Bassett (San Francisco, CA), The Spice Hunter (San Luis Obispo, CA), and Primeline (Miami, FL). The drupes were incubated for wasp emergence under controlled conditions as described previously.

To determine the percentage of the fruits damaged by wasp feeding in both the field-collected and the purchased drupes, a subset of each collection ($n = 20$ with 3 replicates) was dissected. To determine whether there was a year or season effect on wasp impact in the field collections, the number of damaged drupes collected during each year and season was analyzed by a

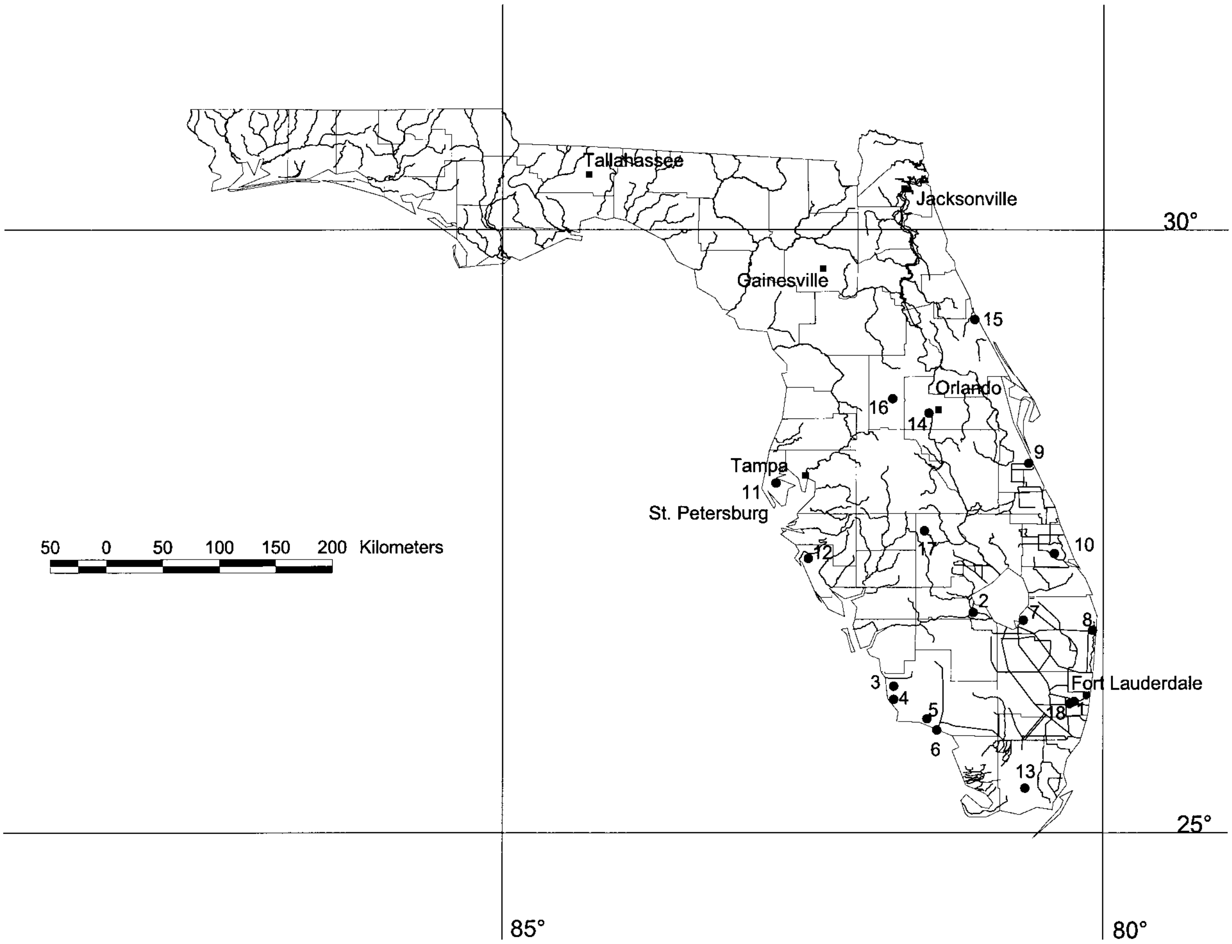

FIG. 1. Map of Florida showing the *S. terebinthifolius* sites sampled during the 2-year period 1997–1999. Circles with accompanying numbers indicate *S. terebinthifolius* drupe collection sites. Numbers next to circles refer to sites described in Table 1. Square symbols mark major cities.

repeated-measures ANOVA (SAS Institute, 1990). Moreover, to determine the impact of regional differences on the incidence of drupe damage, the sites were grouped according to latitude (north of Lake Okeechobee or south thereof) and according to their coastal or inland location (west coast, east coast, or inland). In the area north of Lake Okeechobee and south of Orlando, typically 10–20% of days from December through February have minimum temperatures below 4°C compared with 0–10% of days further south of the north coast of the lake (Winsberg, 1990). Moreover, the coastal areas of peninsular Florida are characterized by mean daily minimum temperatures in January of 12°C compared with 5.5°C for more inland regions (Greller, 1980; Tomlinson, 1980).

Breaking diapause. Wasps of the genus *Megastigmus* are known to emerge enmass initially followed by a prolonged period of apparent diapause that may last several years (Milliron, 1949). After the drupes collected during the fall and winter of year 1 were reared for about 50 days, the wasp emergence appeared to have been complete as no or only a few wasps had emerged during the previous 2 weeks. To determine the influence of photoperiod on latent wasp emergence, these drupes were reared in petri dishes (9 × 1.5 cm) in either a 12:12 h or a 14:10 h light:dark photoperiod. Emerging wasps were counted weekly for nearly 140 days and the rate of wasp emergence was analyzed by ANCOVA (SAS Institute, 1990), comparing the regression coefficients of the wasp emergence while reared in the two photoperiods.

Germination studies. The impact of wasp damage on the viability of *S. terebinthifolius* drupes was determined by germination tests of mature drupes. Initially the optimal conditions for germination of undamaged drupes (lacking emergence holes) were determined by incubation of surface-sterilized (10% sodium hypochlorite, commercial bleach for 10 min) drupes in petri dishes (9 × 1.5 cm) lined with filter paper moistened with deionized water. Incubation conditions were 20, 25, and 30°C in complete darkness for 14 days. An additional treatment included incubation at 25°C in a

TABLE 1

Collection Sites of *S. terebinthifolius* Drupes and the Percentage (± SE) Damaged by *M. transvaalensis* Wasps[a]

			Year 1 (1997–1998)				Year 2 (1998–1999)			
Site No.	Name	County	Winter		Spring		Winter		Spring	
1	UF/FLREC	Broward	31.0	6.3	.[b]	.[b]	28.3	3.3	.	.
2	Moorehaven	Glades	47.3	2.8	.[b]	.[b]	96.7	1.7	45.0	2.9
3	Naples	Collier	34.0	3.6	100.0	.[c]	68.3	9.3	94.4	1.8
4	HW 41	Collier	13.8	2.7	61.0	11.7	30.0	7.6	66.7	3.3
5	Big Cypress Bend	Collier	15.0	5.0	18.2	.[c]	16.7	3.3	20.0	1.8
6	Everglades City	Collier	1.5	1.0	51.5	7.1	1.7	1.7	5.0	2.9
7	Lake Okeechobee	Palm Beach	22.8	2.4	96.0	1.5	35.0	5.0	89.4	2.6
8	West Palm Beach	Palm Beach	29.8	6.6	.[b]	.[b]	40.0	2.9	.[b]	.[b]
9	Melbourne	Brevard	8.3	4.3	64.7	.[c]	21.7	1.7	48.3	6.0
10	Port St. Lucie	St. Lucie	16.7	3.3	22.4	12.4	15.0	2.9	87.5	2.1
11	Clearwater	Pinellas	37.5	5.5	93.0	4.7	28.3	4.4	96.7	1.7
12	Sarasota	Sarasota	13.7	1.9	95.6	1.6	73.3	4.4	.[b]	.[b]
13	Daniel Beard, ENP	Dade	25.7	6.2	.[b]	.[b]	25.0	2.9	88.3	1.7
14	Orlando	Orange	.	.	72.2	5.1	10.0	2.9	96.7	1.7
15	Daytona	Volusia	9.3	2.5	.[b]	.[b]	98.3	1.7	63.3	6.0
16	Clermont	Lake	5.8	2.5	.[b]	.[b]	13.3	4.4	.[d]	.[b]
17	Sebring	Highlands	21.0	3.8	88.3	7.6	13.3	1.7	98.9	0.7
18	Treetops Park	Broward	37.3	2.4	.[b]	.[b]	78.3	6.0	.[b]	.[b]

[a] Estimates derived from dissections of a subset (three replicates of 20 drupes each) of drupes collected from different locations in Florida during two fruiting seasons over a 2-year period.
[b] Fruit were unavailable when site was visited.
[c] Only one replicate was available for analysis.
[d] Site abandoned because of disappearance of host plant.

14:10 h light:dark photoperiod. Four replicates of 10 drupes each were included. After optimal conditions were determined (see Results), paired wasp-damaged (as indicated by a wasp emergence hole) and apparently undamaged drupes were incubated at 20°C in complete darkness to determine the impact of wasp feeding on drupe viability. An additional treatment included drupes collected on the ground from small mammal feces, possibly a raccoon (*Procyon lotor* (L.)). Four replicate incubations of the drupes of the single-feces collection were conducted. Results were analyzed by ANOVA (SAS Institute, 1990) and means were compared with a Ryan's Q multiple comparison test (Day and Quinn, 1989).

Alternate host species. To determine whether this wasp, which was originally reared from South African *Rhus* spp. (Grissell and Hobbs, 2000), had expanded its host range to include other plant species in Florida, collections were made of drupes from native members of the Anacardiaceae at several locations and on several dates throughout the state where these species and *S. terebinthifolius* were in close proximity. The native species included eastern poison ivy (*Toxicodendron radicans* (L.) Kuntze), Florida poisontree or poisonwood (*Metopium toxiferum* (L.) Krug & Urban), and winged sumac (*Rhus copallinum* L.). The taxonomy of these species follows that of Wunderlin (1998). Drupes from eastern poison ivy and winged sumac were also collected north of the *S. terebinthifolius* distribution to determine whether the wasp had spread beyond the range of the weed on these potential alternate hosts. Additionally, fruits of several non-Anacardiaceae species and a nonnative member of this family (*Spondias purpurea* L.) were collected to determine whether the wasp could feed and complete development in species that had fruits of similar size and/or color to that of *S. terebinthifolius*.

RESULTS

Wasp distribution and damage. The results of collections made during both year 1 (1997–1998) and year 2 (1998–1999) indicate that wasps were present at all collection sites (Table 1) and that only the wasp *M. transvaalensis* emerged from *S. terebinthifolius* drupes. Nearly all the wasps that had fed on the drupes had emerged at the time of dissection as only 3 (2 larvae, 1 adult) of more than 4000 drupes dissected were found to contain live wasps. However, this may be an underestimate as wasps could have been overlooked during dissections.

Wasp damage during the fall of year 1 ranged from 3.0 to 50.0% and overall averaged 24.6 ± 3.0% of the drupes. During the winter of year 1, wasp damage was similar 22.3 ± 2.1% and was not significantly different ($P > 0.5$) from that of the fall collection. As no significant difference in the level of damage occurred in the fall and winter collections during year 1, only the win-

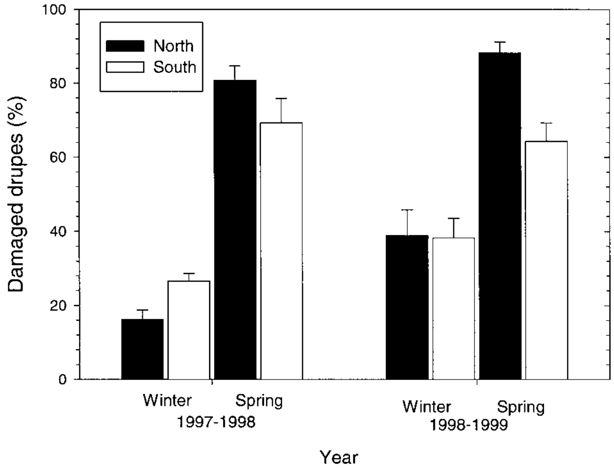

FIG. 2. Mean (± SE) percentage of *S. terebinthifolius* drupes damaged by *M. transvaalensis* wasps during the winter and spring flowering season of year 1 (1997–1998) and year 2 (1998–1999). Significantly more drupes were damaged in the spring than in the winter ($F_{1,15} = 98.92$; $P < 0.0001$). Additionally, significantly more drupes were damaged in the northern (north of Lake Okeechobee) than in the southern sites ($F_{1,15} = 7.50$; $P = 0.0152$).

ter collection was made during year 2 (Table 1). Drupe damage during the winter collections of year 2 averaged 38.5 ± 4.2%. As expected, during the spring, the incidence of fruiting trees was very low; however, fresh drupes could be collected at most sites (Table 1). These drupes had much greater levels of damage during both year 1 (76.3 ± 3.6%) and year 2 (74.8 ± 3.4%) than the winter-collected drupes. Repeated-measures analysis indicated that, regardless of year, a significantly greater percentage of the drupes was found damaged in the spring than in the winter collection (Fig. 2).

To determine the effect of regional factors on the incidence of drupe attack, the 18 sites were grouped according to their latitude (north of Lake Okeechobee or south thereof) and coastal or inland location (west coast, east coast, or inland). Though the difference was small, a greater percentage of the drupes was damaged in the northern sites (57.4 ± 3.5%) than in the southern sites (44.4 ± 2.5%; Fig. 2). Moreover, a significantly greater percentage of damaged drupes was recovered from the inland locations (79.5 ± 5.3%) only during year 2 (Fig. 3).

Damage estimates of the drupes purchased from commercial sources were similar to, and in many cases exceeded, those from our field collections. Average damage estimates were 37.2 ± 0.04% from Primeline, 30.7 ± 0.3% from Morton & Bassett, and 92.3 ± 0.02% from The Spice Hunter drupes. Apparently, the wasps had emerged prior to the time of the purchase as no wasps emerged during observation. However, one dead *M. transvaalensis* wasp was found among the drupes in the container from Primeline. If any wasps were still present in the drupes at the time of purchase, the freeze-drying described on each label undoubtedly affected the wasp viability and their emergence.

Wasp emergence. Following collection of drupes during the fall of year 1 the wasps emerged rapidly, and within 14 days about 50% of the wasps had emerged (Fig. 4). Wasp emergence from drupes collected during the winter of year 1 had a slightly slower rate of emergence; after 21 days about 50% of the wasps had emerged. Following collection of drupes from the winter of year 2, wasp emergence was delayed such that about 50% of the wasps had emerged after 125 days. Finally, about 50% of the wasps had emerged after 13 days from drupes collected during the spring of 1999. Additional statistical analysis of these data was not conducted as the date of oviposition in these field-collected drupes was not known. In all collections, more females than males emerged from the drupes. Female to male ratios ranged from 1.3:1 during winter 1999 to 3.0:1 for the fall 1997 collections.

Breaking diapause. Exposure of *S. terebinthifolius* drupes to different photoperiods influenced the cumulative emergence of *M. transvaalensis* wasps. Wasp emergence was significantly more rapid from drupes incubated in the 12-h photoperiod than in those incubated in the 14-h photoperiod (Fig. 5). Incubation of drupes terminated after 140 days and by this time 189 and 144 wasps had emerged from the 12- and 14-h treatments, respectively.

Germination studies. Preliminary tests indicated that drupe germination was significantly affected by both light and temperature. Drupes exposed to light at 25°C had significantly lower percentage germination than those with the other treatments. The best germi-

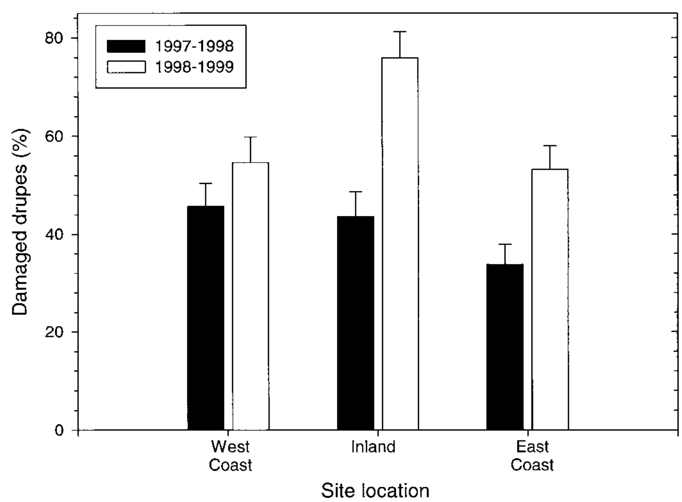

FIG. 3. Mean (± SE) percentage of *S. terebinthifolius* drupes damaged by *M. transvaalensis* wasps during year 1 (1997–1998) and year 2 (1998–1999) from 18 sites at different coastal or inland locations. Significantly more drupes were damaged at the inland sites than at the coastal sites only during year 2 ($F_{2,33} = 8.92$; $P = 0.0008$).

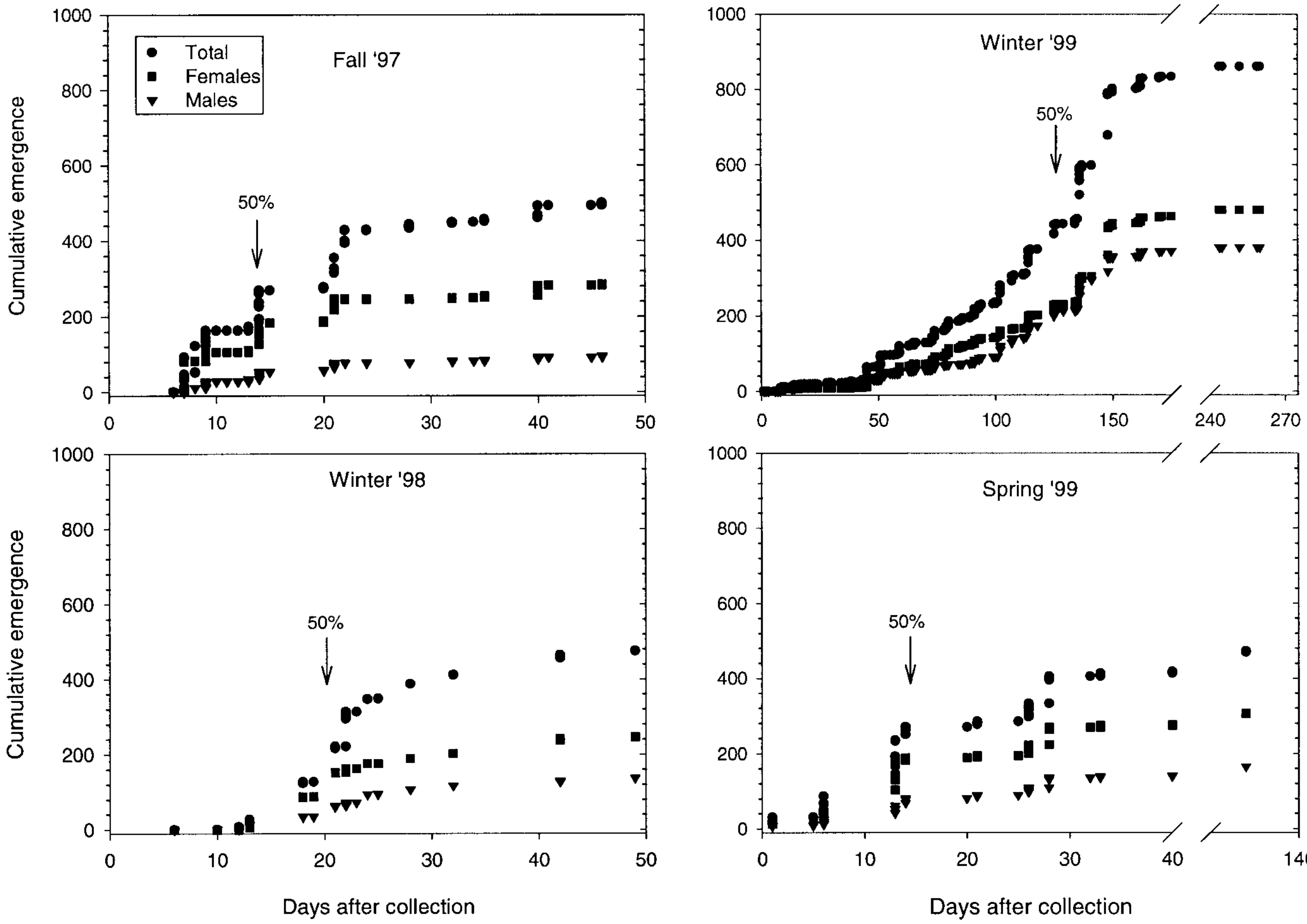

FIG. 4. Cumulative emergence of *M. transvaalensis* wasps from *S. terebinthifolius* drupes collected from 18 sites in Florida during 2 years (1997–1999). Arrows indicate the days after collection when 50% of the wasps had emerged from the drupes. Drupes were incubated at ambient temperatures and photoperiod (1997–1998) or under controlled conditions (1999; 27°C; 14:12 h L:D photoperiod). Wasp emergence dates were not recorded during spring and fall 1998.

nation occurred in darkness at 20°C, where 90% of the drupes germinated (Table 2).

Drupes collected from animal feces incubated at 20°C in darkness had significantly greater percentage germination than either the intact or the wasp-damaged drupes (Table 3). Additionally, none of the wasp-damaged drupes germinated, compared with ca. 46% of the intact drupes. Possibly some of the drupes in this germination test were infested with wasps yet were not recognized as such because of the lack of an exit hole. This would explain the relatively low level of germination in apparently intact drupes.

Alternate host species. Multiple drupe collections were made from native members of the Anacardiaceae of south Florida and one nonnative species, *S. purpurea* (Table 4). The only insects that emerged from any of these collections were two similar chalcidoid wasps, *Megastigmus floridanus* Milliron and *Torymus rugglesi* Milliron from drupes of *Ilex cassine* collected at Mahogany Hammock, Everglades National Park.

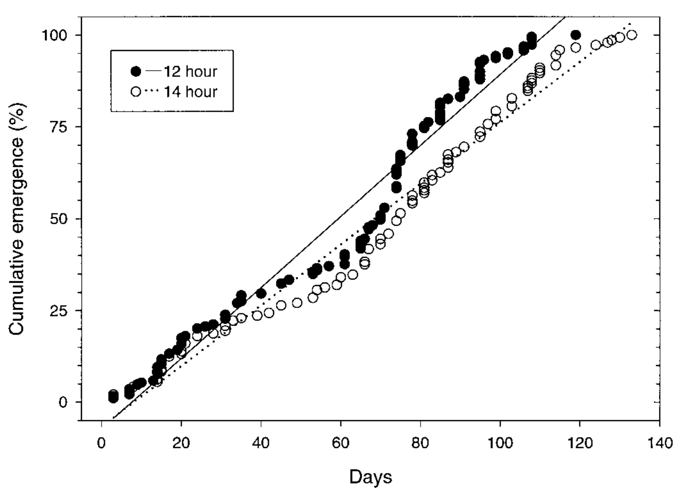

FIG. 5. Cumulative percentage emergence of *M. transvaalensis* wasps from *S. terebinthifolius* drupes exposed to either a 12-h or a 14-h photoperiod. Wasps emerged more rapidly ($F_{1,168} = 29.95$; $P < 0.0001$) from the drupes exposed to the 12-h treatment ($-7.3 + 0.97\times$) than those exposed to the 14-h treatment ($-6.7 + 0.83\times$).

TABLE 2

Preliminary Germination Test for Drupes of *S. terebinthifolius* Incubated under Different Environmental Conditions

Treatment	Mean % germination[a]	SE[b]
20°C/dark	90.0	0.0a
25°C/dark	75.0	5.0ab
30°C/dark	65.0	6.5ab
25°C/light	40.0	17.8b

[a] $F_{3,12} = 4.61$; $P = 0.0229$.
[b] Means followed by the same letter are not significantly different according to a Ryan's Q mean comparison test ($P = 0.05$).

Although these findings are beyond the scope of this study, this is the first report of these species feeding on this host (Grissell, 1989).

DISCUSSION

The wasp *M. transvaalensis* is widely distributed throughout the range of *S. terebinthifolius* in Florida and was recovered from all sites visited. Natural populations of the wasp caused significant damage to the reproductive potential of the weed *S. terebinthifolius*. Overall, during the 2 years of this study, drupe mortality from wasp damage averaged 22.3–38.5% during the primary fruit production period (Nov.–Jan.). In those populations (ca. 10%; Ewel *et al.*, 1982) that had a second fruit production period (June–July), much higher drupe mortality (74.8–76.3%) occurred. These damage levels are considerably higher than those reported in Hawaii, where on average almost 10% of the drupes were damaged by wasps in 1988 (Yoshioka and Markin, 1991). Moreover, they exceed the estimates made for Florida populations in which less than 5% of the drupes were reported damaged (Habeck *et al.*, 1994). However, both these previous determinations are underestimates of the actual level of damage as they were based only on wasp emergence and not on drupe damage. Our results indicate that wasps emerge rapidly from fresh drupes, often within a few days of collection. Therefore, these previous damage estimates that relied only on wasp emergence may have overlooked the wasps that emerged prior to drupe collection. As *S. terebinthifolius* reproduces only by seed, our results indicate that the wasp may have a significant impact on the reproduction and possibly the spread of the weed. Although seed-feeders may not be the best candidates to control perennial weeds (Huffaker, 1973), a concerted attack by a complex of agents may achieve long-term reduction of the weed population (Hoffman and Moran, 1998). Moreover, with the reportedly low seedling survival, especially in mature plant communities (50%; Ewel, 1986), wasp damage may play a role in reducing the spread of this weed species by impeding its invasion into natural areas where it displaces native species.

Typically, the wasp probably has two or more generations per year that are entirely dependent upon the synchronous flower and fruit production periods of its host, *S. terebinthifolius*. The lack of an increase in the rate of wasp damage between the fall and the winter collections of year 1 suggest only a single wasp generation during this period. However, the possibility of a second generation during this period exists as the wasps emerge while susceptible drupes are still available. The increased levels of damage observed during the spring fruit production of both years suggests an additional generation. More detailed studies on the life cycle of the insect are needed to better understand this phenomenon.

Increased levels of damage were observed only during year 2 at the inland sites compared with the two coastal regions. This increase could be due to higher winter temperatures that occurred during this period. The late fall/winter months of year 2 were considerably warmer than the same months of year 1 (NOAA, 1998, 1999). For example, the average minimum temperatures for November and December were 2.3 and 2.5°C warmer, respectively, during year 2 than during the same months of year 1. A slight, but significant, increase in drupe damage also occurred at the northern sites compared with the southern sites. However, in these northern sites late fall/winter minimum temperatures are typically 10°C lower than those at the more southern sites (e.g., Ft. Lauderdale). Whether or not damage levels could be influenced by these temperature differences is not known and additional research is needed to address this issue.

When drupes were incubated under ambient photoperiod and temperature, the rate of wasp emergence appeared to approach a plateau after 30 days, suggesting that either most of the wasps had emerged or the wasps had delayed emergence pending a required environmental cue. This cue may have been the 12-h photoperiod as emergence increased slightly in drupes incubated under these conditions compared with those incubated under 14-h photoperiod conditions. This

TABLE 3

Germination Test to Determine Effect of Wasp Damage on *S. terebinthifolius* Drupe Viability, with Additional Small Mammal Treatment

Treatment	Mean % germination[a]	SE[b]
From feces	82.5	11.8a
Intact	46.3	8.2b
Damaged	0	0c

[a] $F_{2,17} = 30.87$; $P < 0.0001$.
[b] Means followed by the same letter are not significantly different according to a Ryan's Q mean comparison test ($P = 0.05$).

TABLE 4

Collections of Drupes from South Florida Members of the Anacardiaceae (Other Than *S. terebinthifolius*) and Other Families

Family	Species	Location	County	Date
Anacardiaceae	*Mangifera indica* L.	Larry & Penny Thompson[a]	Dade	21-July-99
	Metopium toxiferum (L.) Krug & Urb.	Larry & Penny Thompson[a]	Dade	25-May-99
		Larry & Penny Thompson[a]	Dade	21-Jul-99
		Larry & Penny Thompson[a]	Dade	01-Sep-99
		Long Pine Key[b]	Dade	08-Apr-99
		Long Pine Key[b]	Dade	25-May-99
		Long Pine Key[b]	Dade	21-Jul-99
		Long Pine Key[b]	Dade	01-Sep-99
		Navy Wells[a]	Dade	08-Apr-99
		Navy Wells[a]	Dade	21-Jul-99
		Navy Wells[a]	Dade	01-Sep-99
		Snapper Creek[a]	Dade	25-May-99
	Rhus copallinum L.	Crystal Lake	Gadsen	15-Apr-99
		Larry & Penny Thompson[a]	Dade	06-Oct-99
		Long Pine Key[b]	Dade	08-Apr-99
		Long Pine Key[b]	Dade	21-Jul-99
		Long Pine Key[b]	Dade	06-Oct-99
		Navy Wells[a]	Dade	08-Apr-99
		Navy Wells[a]	Dade	27-May-99
		Navy Wells[a]	Dade	21-Jul-99
		Navy Wells[a]	Dade	06-Oct-99
		Tallahassee	Leon	15-Apr-99
		Three Rivers	Jackson	15-Apr-99
	Spondias purpurea L.	Charlotte Harbor	Charlotte	16-Mar-99
	Toxicodendron radicans (L.) Kuntze	Okeeheelee Nature Center	Palm Beach	27-May-98
		Gumbo Limbo Trail[b]	Dade	08-Apr-99
		South Daytona	Volusia	14-Apr-99
Aquifoliaceae	Ilex cassine L.	Mahogany Hammock[b]	Dade	08-Mar-99
		Ft. Meyers	Lee	16-Mar-99
Myrsinaceae	*Rapanea punctata* (Lam.) Lundell	HWY 858	Collier	16-Mar-99
		Snapper Creek[a]	Dade	25-May-99
Fabaceae	*Abrus precatorius* L.	Charlotte Harbor	Charlotte	16-Mar-99
Smilacaceae	*Smilax auriculata* Walter	Charlotte Harbor	Charlotte	16-Mar-99
Sapindaceae	*Sapindus saponaria* L.	Charlotte Harbor	Charlotte	16-Mar-99

[a] Miami–Dade Co. Parks.
[b] Everglades National Park.

12-h day length is similar to that found during the fall in southern Florida just prior to *S. terebinthifolius* flowering. However, the day length during the spring flowering is much longer, nearly 14 h, suggesting that other environmental cues may be important for synchronization of the wasp's life cycle with respect to that of its host.

The adventive wasp species *M. transvaalensis* was first reported from *S. molle* in South Africa over 40 years ago (Hussey, 1956). The redistribution of this wasp may have been facilitated by the worldwide pink peppercorn trade (Habeck *et al.*, 1989; Grissell and Hobbs, 2000). All three commercial sources of pink peppercorns that we purchased were allegedly *S. terebinthifolius* imported from Réunion, an island off the eastern coast of South Africa. Our results indicate that this wasp was present in at least one commercial source of pink peppercorns. Furthermore, dissections of the drupes from all three sources indicated damage that was consistent with *M. transvaalensis* feeding. Therefore, these results suggest that the pink peppercorn importation from Réunion could explain the wasp's occurrence in North America. The possibility for additional modes of introduction of the wasp exist, such as infested *S. terebinthifolius* drupes introduced as ornamental plants (Grissell and Hobbs, 2000) or wreaths available at hobby stores for holiday decorations (G. S. Wheeler, personal observation).

As the wasp is thought to originate from South African *Rhus* spp. (Grissell and Hobbs, 2000), it would not be surprising to find this species feeding on Florida's native *Rhus* or other related species. In Florida, *M. transvaalensis* wasps have been reared only from *S. terebinthifolius* fruits. Despite numerous collections of several south Florida native Anacardiaceae species, no wasps were found attacking any plant except *S. terebinthifolius*. Only one other species of this family, *Toxicodendron vernix* (L.) Kuntze, has a distribution that overlaps that of *S. terebinthifolius* (Wunderlin, 1998). However, the susceptibility of this species has yet to be determined. Surveys of the herbivores associated with poison ivy, *T. radicans*, were conducted in Florida, but no mention was made of fruit-feeding species (Habeck, 1990). Even though several species of the Anacardiaceae may be undesirable irritants to humans, the fruit and leaves are important food for native birds and small mammals (Martin *et al.*, 1951). If this wasp successfully exploits native plant species, thereby threatening the stability of their populations, the value of this species as a *S. terebinthifolius* control agent will be controversial. Finally, assuming that the South African origin of this wasp species is correct (Habeck *et al.*, 1989; Grissell and Hobbs, 2000), by it feeding upon a South American host this represents a new association between the weed and the wasp (Hokkanen and Pimentel, 1984). It has been argued that importation of species for biological control that have no evolutionary history with the target weed may be more successful at controlling the pests. One criticism of the new association approach is that they are more polyphagous and therefore a greater environmental risk than old association species as they are originally found on a host species other than the target weed (Goeden and Kok, 1986). However, we have yet to find evidence of any native plant use by this species in Florida.

ACKNOWLEDGMENTS

We are indebted to the technical assistance of Ben Montgomery, Tracy Davern, Penny Lieberman, and Jamie Zahniser, AmeriCorps, Students Conservation Association, and to Drs. E. E. Grissell and S. D. Hight for reviewing previous versions of the manuscript. Dr. W. Mashaka assisted in collections made in Everglades National Park (Permit Nos. 19970114 and 19990011) and Ms. Laurie McHargue assisted in collections made in Miami–Dade Co. Parks (Permit No. 0007). Collections were made with the cooperation of the Florida Department of Environmental Protection (Permit No. 1065), which also provided financial assistance. Insect identifications were generously provided by Dr. E. E. Grissell, Systematic Entomology Laboratory, National Museum of Natural History, Washington, DC. Voucher specimens were deposited at the Everglades National Park and the National Museum of Natural History. This is Florida Agricultural Experiment Station Journal Series No. R-07915.

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